PHILOSOPHICAL

TRANSACTIONS.

I. *A Synoptic Scale of Chemical Equivalents. By* William Hyde Wollaston, *M. D. Sec. R. S.*

Read November 4, 1813.

When the nature of any saline compound is proposed as the subject of inquiry to an analytic chemist, the questions that occur for his consideration are so varied and so numerous, that he will seldom be disposed to undertake a series of original experiments for the purpose of satisfying his inquiries, so long as he can rely upon the accuracy of those results that have been obtained by the labour of others, who have preceded him in this field of patient investigation.

If, for instance, the salt under examination be the common blue vitriol, or crystallized sulphate of copper, the first obvious questions are, (1) How much sulphuric acid does it contain? (2) How much oxide of copper? (3) How much water? He may not be satisfied with these first steps in the analysis, but may desire to know further the quantities (4) of sulphur, (5) of copper, (6) of oxygen, (7) of hydrogen. As means of gaining this information, he naturally considers the quan-

tities of various reagents that may be employed for discovering the quantity of sulphuric acid, (8) how much barytes, (9) carbonate of barytes, or (10) nitrate of barytes, would be requisite for this purpose; (11) How much lead is to be used in the form of (12) nitrate of lead; and when the precipitate of (13) sulphate of barytes or (14) sulphate of lead are obtained, it will be necessary that he should also know the proportion which either of them contains of dry sulphuric acid. He may also endeavour to ascertain the same point by means of (15) the quantity of pure potash, or (16) of carbonate of potash requisite for the precipitation of the copper. He might also use (17) zinc or (18) iron for the same purpose, and he may wish to know the quantities of (19) sulphate of zinc, or (20) sulphate of iron that will then remain in the solution.

These, and very many more questions of the same kind, which it would be tedious to specify, and needless to enumerate, engage the thoughts, and will occupy much of the time of every experimental chemist, unless he can have recourse to some record of former analyses on which he can depend.

The scale, which I am about to describe, is designed to answer at one view all these questions, with reference to most of the salts contained in the table, not merely expressing numerically the proportions by which the desired answers may be calculated, but directly indicating the actual weights of the several ingredients, contained in any assumed weight of the salt under consideration, and also the actual quantities of several reagents that may be used, and of the precipitates that would be obtained by each.

In the formation of this scale, it is requisite in the first place

to determine the proportions in which the different known chemical bodies unite with each other, and to express these proportions in such terms that the same substance shall always be represented by the same number.

It is to RICHTER that we are originally indebted for this mode of expression, and for having first observed that law of permanent proportions on which the possibility of this numerical representation is founded. The proportions assigned to various salts by his predecessors BERGMAN, WENZEL, KIRWAN, were incompatible with this mode of notation. If we turn to BERGMAN's treatise *De Analysi Aquarum*, we find it stated that in sulphate of potash 40 of acid are combined with 52 of potash, or that 100 of sulphuric acid take 130 of potash. In muriate of potash, 61 of the alkali are said to be combined with 31 of acid, which is in the proportion of 130 to 66. So that the same quantity of potash that is saturated by 100 sulphuric acid, requires of muriatic 66.

But if we make a similar estimate by means of lime, since sulphate of lime is said to contain 46 acid combined with 32 lime, 100 of acid would require 69,5. And in muriate of lime, since 44 of lime are said to be combined with 31 of acid, thence 69,5 of lime would require 49. So that in this instance it would appear that the equivalent to 100 sulphuric acid, instead of being 66 muriatic, is 49; which, if true, would defeat our attempts to express the same body always by the same number.

In comparing the analyses of WENZEL with each other, we find the same inconsistency. If we select sulphate of ammonia, and muriate of ammonia, we obtain 67,3 as the equivalent of muriatic acid. But by comparison of sulphate of magnesia

with muriate of magnesia, it would appear to be 73 instead of 67,3.

In recurring to the tables of KIRWAN, a similar obstacle presents itself to the determination of the quantity of muriatic acid, that is equivalent to a given weight of sulphuric acid. When the comparison is made by means of potash, the result would make it appear that 68,3 is the relative weight of muriatic acid. But, if the compounds of these acids with lime be employed in the computation, the result instead of 68,3 gives only 59.

RICHTER remarked, on observing this sort of inconsistency, that if sulphate of potash formed according to the proportions of KIRWAN were decomposed by muriate of lime, there should be found a large excess of alkali in the solution. But, on the contrary, by direct experiment he found that neutral salts, when mixed, remained in all cases neutral, and consequently, that the same weight of muriatic acid would in all cases be found equivalent to the same quantity of sulphuric acid; and therefore might be conveniently expressed in stating the composition of salts, by the same number. He estimates this acid at 712, as the equivalent to 1000 dry sulphuric acid, the number assumed as his standard of comparison, to which all other numbers for acids, alkalies, and earths are adapted.

It could not escape the penetration of M. BERTHOLLET, that there exist numerous deviations from this law of neutralization, and cases of prevailing affinity dependent on a redundance of one or other ingredient in a mixture of salts. But he was not so happy in detecting the definite law, by which many, at least, of these deviations are governed. It has since been found, that when a base unites with a larger portion of acid

than is sufficient to saturate it, the quantity combined is then an exact simple multiple of the former, thus exhibiting a new modification of the law of definite proportions, rather than any exception to it.

The first instance in which the same body was supposed to unite with different doses of another, in such proportions that one of these doses is a simple multiple of the other, was noticed by Mr. HIGGINS, who conceived, rather than actually observed to occur, certain successive degrees of oxidation of azote, and represented the series of its combinations with oxygen to be

* Azote 1 with 2 oxygen making nitrous gas.
Azote 1 with 3 oxygen making red nitrous vapour.
Azote 1 with 4 oxygen making yellow nitrous acid.
Azote 1 with 5 oxygen making white nitric acid.

He at the same time added his opinion, that such are the proportions in which these gases unite to each other by *bulk*, having before observed one instance of union by exactly double bulk in the formation of water by the combustion of hydrogen and oxygen, and expressed his persuasion that the number of particles in a given bulk of the different gases is the same, and that the number of particles in the compounds of azote and oxygen, are successively in the proportions above stated.

But though Mr. HIGGINS, in the instance of the union of hydrogen with oxygen, anticipated the law of bulks observed by M. GAY LUSSAC, with respect to the union of gases, and in his conception of union by ultimate particles clearly preceded Mr. DALTON in his atomic views of chemical combination, he appears not † to have taken much pains to ascertain

* A comparative View of the phlogistic and antiphlogistic theories, 1789, p. 133.

† In straw-coloured nitrous acid, the proportion *appears* to be four to one; but

the actual prevalence of that law of multiple proportions by which the atomic theory is best supported, and it is in fact to Mr. DALTON that we are indebted for the first correct observation of such an instance of a simple multiple in the union of nitrous gas with oxygen. In his endeavours to determine the composition of the atmosphere, he found that the quantity of oxygen contained in 100 measures of common air would combine with either 36 or 72 measures of nitrous gas, according to certain variations in the mode of conducting the experiment.*

Chemists in general, however, appear to have been by no means duly impressed with the importance of this observation of Mr. DALTON, till they were in possession of other facts observed by Dr. THOMSON and myself,† in a more tangible form, with regard to neutral and superacid or subacid salts, which could be made the subjects of more deliberate and less equivocal experiments; and it is, perhaps, owing to the repetition and confirmation of them by M. BERTHOLLET,‡ that they have attracted the attention of other chemists, who are now ready to admit that the term binacid correctly expresses the relation of many superacid salts to neutrals consisting of the same ingredients. Since that time the additional instances in which the same law has been observed to prevail, are become so numerous, especially with regard to different degrees of oxidation, that we have the greatest reason to presume that

the colourless contains *about* five of dephlogisticated to one of phlogisticated air. Comparative View, p. 84.

* Manchester Mem. Vol. V.—NICH. Journal, Vol. XIII. p. 433.

† Phil. Trans. 1808, p. 74.—Ditto, p. 96.

‡ Mem. d'Arcueil, Tome II. p. 470.

it is universal, and that in such analyses as are found not to accord with this general observation, we are warranted in suspecting some degree of inaccuracy in one or other of the results compared together.

According to Mr. DALTON's theory, by which these facts are best explained, chemical union in the state of neutralization takes place between single atoms of the substances combined; and in cases where there is a redundance of either ingredient, then two or more atoms of this kind are united to only one of the other.

According to this view, when we estimate the relative weights of equivalents, Mr. DALTON conceives that we are estimating the aggregate weights of a given number of atoms, and consequently the proportion which the ultimate single atoms bear to each other. But since it is impossible in several instances, where only two combinations of the same ingredients are known, to discover which of the compounds is to be regarded as consisting of a pair of single atoms, and since the decision of these questions is purely theoretical, and by no means necessary to the formation of a table adapted to most practical purposes, I have not been desirous of warping my numbers according to an atomic theory, but have endeavoured to make practical convenience my sole guide, and have considered the doctrine of simple multiples, on which that of atoms is founded, merely as a valuable assistant in determining, by simple division, the amount of those quantities that are liable to such definite deviations from the original law of RICHTER.

Having some time since computed for private use a series of supposed atoms, I had assumed oxygen as the decimal unit of my scale, in order to facilitate the estimation of those

numerous combinations which it forms with other bodies. But, though in the present table of Equivalents, I have retained the same unit, and have taken care to make oxygen equally prominent for the same reason as before, as well as on account of the important part it performs in determining the affinities of bodies by the different proportions in which it is united to them; nevertheless the real measure, by which most bodies are compared to each other, in any experiments that I have made, and to which I have, in fact, endeavoured to find equivalents, is a determinate quantity of carbonate of lime. This is a compound, that may be regarded as most distinctly neutral. It is most easy to obtain in a state of uniform purity; most easy to analyse (as a binary compound); it is a most convenient measure for the powers of acids, and affords the most distinct expression for the comparative neutralizing powers of alkalies.

The first question, consequently, to be resolved is, by what number are we to express the relative weight of carbonic acid, if oxygen be fixed at 10. It seems to be very well ascertained, that a given quantity of oxygen yields exactly an equal measure of carbonic acid by union with carbon; and since the specific gravities of these gases are as 10 to 13,77,* or as 20 to 27,54, the weight of carbon may be justly represented by 7,54, which, in this instance, is combined with 2 of oxygen forming the deutoxide, and carbonic oxide being the protoxide will be duly represented by 17,54.

Carbonic acid having consequently been assumed as 27,54, it follows from the analysis of carbonate of lime, which by heat loses 43,7 per cent. of acid, and leaves 56,3 of base, that they

* BIOT and ARAGO 1,1036 : 15196 : : 10 : 13,77.

are combined in the proportion of 27,54 to 35,46, and consequently that lime must be represented by 35,46, and carbonate of lime by 63.

If I would proceed in the series for the purpose of estimating the reliance to be placed on preceding analyses, I might dissolve 63 of carbonate of lime in muriatic acid, and by evaporating to perfect dryness should obtain about 69,56* muriate of lime, and by deducting the weight of the lime 35,46 should learn, by means of the difference 34,1, what is to be considered as dry muriatic acid.

But since lime is now known, by the brilliant discoveries of Sir H. DAVY, to be a metallic body united with oxygen, this salt may also be viewed as a binary compound in a different light as oxymuriate of calcium; in which case we must transfer the weight of 10 oxygen to the muriatic acid, making 44,1 of oxymuriatic acid combined with 25,46 calcium. Or, lastly, if with the same distinguished chemist, we regard it as chlorid of calcium, its place in the scale of equivalents is the same 69,56, and the portion of matter here added to the calcium, whether it retain its late name of oxymuriatic acid, or revert to its original one of dephlogisticated marine acid, or assume its new one of chlorine, will be rightly represented by 44,1, which expresses a bare fact without reference to any theory, and affords the means of estimating the proportion of this constituent in all muriatic compounds, without need of controversy respecting its simple or compound nature, which may

* In Dr. MARCET's experiments on the composition of muriate of lime, referred to in his Analysis of the Water of the Dead Sea,

50,77 carbonate gave 56,1 of muriate of lime,

and 50,77 : 56,1 : : 63 : 69,6.

never admit of any argument that will be deemed conclusive by all parties.

With the same latitude of interpretation may be understood muriate of potash or of soda in the scale of equivalents; and the relative weights of mere potash or soda may, perhaps, be determined better by means of these compounds than by any other, because they are not liable to be superacid, and are not decomposed by heat.

If to a quantity of muriatic acid, which, by previous trial, I know would dissolve 100 carbonate of lime, I add 100 grains of crystallized carbonate of potash, and after the addition find that it will dissolve only 49,8 of carbonate of lime; I hence infer that 100 of this carbonate is equivalent to 50,2 carbonate of lime, and consequently that 125.5 is the equivalent to 63 in the table.

Next, if I combine 125,5 of crystallized carbonate of potash with an excess of muriatic acid, and evaporate to dryness, I expel the whole of the water with all redundant acid, and I find 93,2 of neutral salt; and whether I call it muriate of potash, or chlorid of potassium, or by any other name, with any other views, I may deduct 34,1 as dry muriatic acid, (whether real or imaginary*) and infer the equivalent for potash to be 59,1, even though there should, in fact, be only 49,1 of potassium present, requiring 10† of oxygen to convert it into potash.

* Its separate existence is certainly imaginary, for it can no more be obtained uncombined than dry sulphuric acid, or dry nitric acid.

† If all the steps in the series, by which the number 49,1 is inferred, be correct, this should be exactly 10,00 without any fraction; and the proportion assigned to muriate of potash by BERZELIUS is sufficiently near, to shew that there can be no considerable error. 83,02 : 16,98 : : 49,1 : 10,04.

The next question that occurs relates to the composition of this crystallized carbonate of potash, which I am induced to call bi-carbonate of potash, for the purpose of marking more decidedly the distinction between this salt and that which is commonly called a subcarbonate,* and in order to refer at once to the double dose of carbonic acid contained in it. With reference to carbonate of lime also, I must necessarily consider it as a supercarbonate, for if I add a solution of this salt to a neutral solution of muriate of lime, a considerable effervescence takes place, from a redundance of carbonic acid beyond what is necessary to saturate the lime. If I saturate 125,5 of this salt with nitric acid, taking due precautions not to expel any of the fluid along with the gas which escapes, it loses about 55 of carbonic acid, which is the double of 27,5. But if, previous to the saturation, I heat the salt moderately red, it loses 38,8, consisting of 27,5 carbonic acid and 11,3 water, after which the addition of an acid expels only 27,5, or a single dose of carbonic acid.†

I have in this experiment made use of nitric acid, in order that the resulting compound might guide me in the selection from among former estimates which are extremely discordant with regard to the equivalent of that acid. The proportion of nitrate of potash, which I have obtained by evaporating such a solution by a heat just sufficient to fuse the residuum, gave at the lowest in three experiments 126, for the equivalent of nitrate of potash; from which, if we deduct 59,1 potash,

* I avoid using the term carbonate of potash for either of these salts, because it has been applied to both, and consequently is liable to be misunderstood when standing alone.

† Phil. Trans. 1808, p. 97.

there will remain 66,9 as the apparent equivalent of dry nitric acid. Consequently, I have no hesitation in preferring the estimate * to be obtained from RICHTER'S analysis of nitrate of potash, which gives 67,45, from which if we subtract one portion of azote 17,54, there remain 49,91, so nearly 5 portions of oxygen, that I consider the truth to be 17,54 + 50, or 67,54.

From this sketch of the mode in which such an inquiry may be pursued, wherever it is necessary to make any original experiments, it will be fully understood what is meant by equivalents, and in what manner the series might be continued. I have, however, in most instances drawn my inferences from former analyses, and indeed in all, where I could find coincidences between different authorities sufficient to give confidence in their results.

But with respect to oxalic acid, I again found a difficulty in deciding among the discordant results of different analyses, and was obliged to have recourse to direct experiment.

100 grains of bin-oxalate of potash (commonly called salt of sorrel) were subjected to a degree of heat sufficient to destroy the oxalic acid, and to convert the salt into a subcarbonate of potash. A quantity of muriatic acid was then poured on this residuum, and afterwards saturated with carbonate of lime; and an equal quantity of the same acid was saturated with carbonate of lime alone. By the excess of carbonate dissolved in the latter instance, it was found that 100 bin-oxalate was equivalent to 40,9 carbonate of lime; and hence the equivalent to 63 carbonate of lime will be 154 of the bin-oxalate of potash. After deducting 59,1 potash, the remainder

* 46,7 : 53,3 : : 59,1 : 67,45 quoted in Mem. d'Arcueil, II. 59.

94,9 divided by 2, gives 47,45 for the equivalent of dry oxalic acid. I therefore again adopt the result of the very industrious and ever accurate BERZELIUS, obtained by means of oxalate of lead, that 296,6* litharge are combined with 100 oxalic acid, which are in the proportion of 139,5 litharge to 47,0 oxalic acid. Such a degree of accordance between methods totally different appears highly satisfactory, and seems to shew that in attempts to determine the same point by means of lime, some compounds may possibly be formed at the same time differing in the proportions of acid and base, as in the cases of oxalate and bin-oxalate of strontia, observed by Dr. THOMSON, and that erroneous inferences may have been drawn from precipitates in which they are blended.

With the exception of those instances that I have enumerated, there are few in which I have found it necessary to make any new experiments, as I have met with coincidences between the independent results of others sufficient to satisfy me of their correctness; and accordingly I have adopted such determinations without any pretensions to improve upon them by new experiments of my own.

It is not my design in the table which follows this paper, to attempt a complete enumeration of all those elements or compounds which I suppose to be well ascertained, but merely to include some of those which most frequently occur. I do not offer it as an attempt to correct the estimates that have been formed by others, but as a method in which their results may be advantageously applied in forming an easy approximation to any object of our inquiries.

The means by which this is effected may be in part understood by inspection of the Plate I., in which will be seen the

* Ann. de Chimie, No. 243.

list of substances intended to be estimated, arranged on one or the other side of a scale of numbers in the order of their relative weights, and at such distances from each other, according to their weights, that the series of numbers placed on a sliding scale can at pleasure be moved, so that any number expressing the weight of a compound may be brought to correspond with the place of that compound in the adjacent column. The arrangement is then such, that the weight of any ingredient in its composition, of any reagent to be employed, or precipitate that might be obtained in its analysis, will be found opposite to the point at which its respective name is placed.

In order to shew more clearly the use of this scale, the Plate exhibits two different situations of the slider, in one of which oxygen is 10, and other bodies are in their due proportion to it, so that carbonic acid being 27,54, and lime 35,46, carbonate of lime is placed at 63.

In the second figure, the slider is represented drawn upwards till 100 corresponds to muriate of soda; and accordingly the scale then shews how much of each substance contained in the table is equivalent to 100 of common salt. It shews, with regard to the different views of the analysis of this salt, that it contains 46,6 dry muriatic acid, and 53,4 of soda, or 39,8 sodium, and 13,6 oxygen; or if viewed as chlorid of sodium, that it contains 60,2 chlorine, and 39,8 sodium. With respect to reagents, it may be seen that 283 nitrate of lead, containing 191 of litharge employed to separate the muriatic acid, would yield a precipitate of 237 muriate of lead, and that there would then remain in solution nearly 146 nitrate of soda. It may at the same time be seen, that the acid in this quantity of salt would serve to make 232 corrosive sublimate contain-

ing 185,5 red oxide of mercury, or would make 91,5 muriate of ammonia, composed of 6 muriatic gas (or hydromuriatic acid) and 29,5 ammonia. The scale shews also, that for the purpose of obtaining the whole of the acid in distillation the quantity of oil of vitriol required is nearly 84, and that the residuum of this distillation would be 122 dry sulphate of soda, from which might be obtained, by crystallization, 277 of GLAUBER salt containing 155 water of crystallization. These and many more such answers appear at once by bare inspection, as soon as the weight of any substance intended for examination is made by motion of the slider correctly to correspond with its place in the adjacent column.

With respect to the method of laying down the divisions of this scale, those who are accustomed to the use of other sliding-rules, and are practically acquainted with their properties, will recognise upon the slider itself the common GUNTER's line of numbers, (as it is termed) and will be satisfied that the results which it gives are the same that would be obtained by arithmetical computation.

Those who are acquainted with the doctrine of ratios, and with the use of logarithms as measures of ratios, will understand the principle on which this scale is founded, and will not need to be told that all the divisions are logometric, and consequently that the mechanical addition and subtraction of ratios here performed by juxta-position, corresponds in effect to the multiplication and division of the numbers by which those ratios are expressed in common arithmetical notation.

To others who are not equally conversant with the nature of logarithms, and consequently have not so correct a conception of the magnitudes of ratios, some further explanation of

the mode in which the scale of equivalents is constructed, will, I presume, be acceptable.

They will observe, that the series of natural numbers are not placed at equal intervals on the scale; but that at all equal intervals are found numbers which bear the same proportion to each other. In fig. 3, some of the larger intervals alone are represented on a line similarly divided. The succession of intervals, marked A, B, C, D, E, are all equal, and at these points of division are placed numbers 1, 2, 4, 8, 16, which increase progressively by the same ratio. And since the series 3 : 6 : 12 : 24 increase in the same ratio of 1 to 2, these intervals *a*, *b*, *c*, *d*, *e*, are the same as the former. At another succession of different yet equal intervals, marked F, G, H, I, are placed numbers 1, 3, 9, 27, which increase regularly by an equal ratio of 1 to 3; and by means of a pair of compasses it would be found that the interval from 2 to 6, or from 6 to 18 (which are in the same ratio of 1 to 3,) is exactly equal to FG, the interval between 1 and 3. As any single space represents any one ratio, so the sum of any 2 or 3 equal spaces represent a double or triple ratio. If 1 be increased three times by the ratio of 1 to 2, it becomes 8, which bears to 1 triple the ratio of 2 to 1. This ratio is therefore rightly represented by AD, which is the triple of AB.

The distances of the intermediate numbers 5, 7, 10, 11, 13, &c. from 1 are likewise made proportional to the ratios which they bear to 1, and are easily laid down by means of a table of logarithms; for as these are arithmetic measures of the ratios which all numbers bear to unity, the spaces proportional to them become linear representations of the same quantities.

As the entire spaces AD, AE represent the ratios of 8 and of 16 respectively to 1, so the difference DE represents the ratio of 8 and 16, which stand at D and E, to each other. And in the same manner, any other space *kl* represents correctly the ratio of 7 to 13; so that the measure of a fraction expressed by quantities that are incommensurate is rendered as obvious to sight, as that of any simple multiple. And if a pair of compasses be opened to this interval, and transferred to any other part of the scale, the points of the compasses will be found to rest upon numbers bearing the same proportion to each other as those from which the interval was transferred.

It is exactly in this manner, that the various points in the column of equivalents indicate the several quantities sought in any given position of the slider. The relative distances, at which the articles are placed, represent so many different openings of the compasses rendered permanent and presented to view at once. In the table, which I shall place at the end of this communication, the relation of the various substances enumerated to each other is expressed by numbers. In the engraved scale of equivalents, the ratios of these numbers are represented by logometric intervals at which they are placed, their several positions being determined by those of their respective numbers on the slider, which is logometrically divided. Consequently all the several points in the column of equivalents will indicate numbers in the same due proportions to each other, whatever part of the scale may be presented to them. Those who seek information may obtain it by inspection; those who already possess it, may be able to correct the positions of some articles by direct comparison with the best

analyses upon record, in whatever numbers the results of those analyses may happen to be expressed.

I hope, that without trespassing too much on the time of the Society, I shall have rendered the principle and practical use of this scale intelligible. I trust, that it will prove useful as an assistant to chemists in general. It will at least serve for a specimen of the extreme facility of mechanical approximation, which may very frequently be advantageously substituted for computations, that are often more laborious than the accuracy of our data warrants; and if it tend to introduce into more general use, that valuable instrument the common sliding-rule, it will be the means of saving no inconsiderable portion of time to those who are engaged in scientific pursuits.

Numerical Table of Equivalents.

Hydrogen -	(*a*)	1,32				
Oxygen - -		10,00				
Water - -		11,32				
Carbon -	(*b*)	7,54	+ 20	Oxygen	= 27,54	Carbonic acid.
Sulphur - -	(*f*)	20,00	+ 30	Oxyg.	= 50	Sulphuric acid.
Phosphorus -	(*g*)	17,40	+ 20	Oxyg.	= 37,4	Phosphoric acid.
Azote - -	(*o*)	17,54	+ 50	Oxyg.	= 67,54	Nitric acid (*q*).
Muriatic Acid (dry)	(*e*)	34,1	+ 10	Oxyg.	= 44,1	Oxymuriatic acid.
Chlorine - -		44,1	= Oxymur. acid + 1,32	Hydrog.	= 45,42	Muriatic gas.
Oxalic acid - -	(*b*)	47,0				
Ammonia -	(*p*)	21,5				
Soda - -	(*l*)	39,1	— 10	Oxyg.	= 29,1	Sodium.
Potash - -	(*m*)	59,1	— 10	Oxyg.	= 49,1	Potassium.
Magnesia -	(*n*)	24,6				
Lime - -	(*c*)	35,46	— 10	Oxyg.	= 25,46	Calcium.
Strontia -	(*k*)	69,				
Barytes - -	(*i*)	97,				
Iron - -	(*r*)	34,5	+ 10	Oxyg.	= 44,5	Green Oxid of Iron.
			+ 15	Oxyg.	= 49,5	Red Oxid.

Copper -	(*l*)	40,	+ 10 Oxyg. = 50, Black Oxid of Copper.
Zinc - -	(*s*)	41	+ 10 Oxyg. = 51, Oxid of Zinc.
Mercury -	(*v*)	125,5	+ 10 Oxyg. = 135,5 Red Oxid Mercury.
			+ 125,5 ☿ = 261 Protoxid ☿.
Lead - -	(*d*)	129,5	+ 10 Oxyg. = 139,5 Litharge.
Silver -	(*u*)	135,	+ 10 Oxyg. = 145, Oxid Silver in Muriate.
Subcarb. of Ammonia		49,0	+ 27,5 C. acid = 76,5 Bi-Carb. of Ammonia.
Subcarb. of Soda -		66,6	+ 27,5 C. acid + 11,3 Water = 105,5 Bi-Carb. of Soda.
Subcarb. of Potash -		86,	+ 27,5 C. acid + 11,3 Water = 125,5 Bi-Carb. of Potash.
Carbonate of Lime		63	
——— Barytes -		124,5	
——— Lead -		167,	
Sulphuric acid (dry)		50,	+ 1 Water 11,3 = 61,3 Oil of Vitriol (sp. gr. 1,85).
Sulphate of Soda -		89,1	+ 10 Water 113,2 = 202,3 Glauber Salt.
———Potash -		109,1	
———Magnesia	(*n*)	74,6	+ 7 Water 79,3 = 153,9 Epsom Salt.
———Lime		85,5	+ 2 Water 22,64 = 108,1 Selenite.
———Strontia -		119,0	
———Barytes -		147,0	
———Copper -		156,6	= 1 Acid + 1 Oxid. + (w) 5 Water 56,6.
———Iron -		173,8	= 1 Acid + 1 Oxid. + 7 Water 79,3.
———Zinc - -		180,2	= 1 Acid + 1 Oxid. + 7 Water 79,3.
———Lead -		189,5	
Nitric acid (dry)	(*q*)	67,54	+ 2 Water 22,64 = 90,2 Liquid Nitric acid (sp. gr. 1,50).
Nitrate of Soda -		106,6	
——— Potash -		126,6	
——— Lime -		103,0	
——— Barytes -		164,5	
——— Lead -		207,0	
Muriate of Ammonia -		66,9	= 1 Acid + 1 Amm. + 1 Water.
——— Soda -		73,2	
——— Potash -		93,2	+ 60 Oxygen = 153,2 Hyper-Oxymuriate of Potash.
——— Lime -		69,6	
——— Barytes -		131,0	+ 2 Water 22,6 (w) 153,6 Crystallized Mur. Barytes.
——— Lead -		173,6	
——— Silver -		179,1	
Corrosive Sublimate -		170,1	= 1 Acid 1 Oxyg. + 1 Mercury.
Calomel - -		296,1	= 1 Acid + 1 Oxyg. + 2 Mercury.
Phosphate of Lead -		176,9	
Oxalate of Lead -		186,5	
Bin-Oxalate of Potash		153,0	= 2 Acid + 1 Potash

Data on which the Table is founded.

						10,00	Oxygen
Composition of Water	(1)	88,286	: 11,714	:: Oxygen	10	: 1,327	Hydrogen (*a*)
						11,327	Water
Specific Gravities -	(2)	1,1036	: 1,5196	:: 2 Oxygen	20	· 27,54	Carbonic acid (*b*)
Carbonate of Lime	(3)	43,7	: 56,3	:: Carb. acid	27,54	: 35,46	Lime (*c*)
Carbonate of Lead	(4)	16,5	: 83,5	:: Carb. acid	27,54	: 139,5	Litharge
						10	
						129,5	Lead (*d*)
Litharge - -	(5)	7,15	: 92,85	:: Oxygen	10	: 129,7	
Muriate of Lime from Carbonate of Lime	(6)	50,77	: 56,1	:: Carb. Lime	63	: 69,6	Mur. Lime
					Lime	35,5	
						34,1	Muriatic acid (*e*)
Muriate of Lead -	(7)	409,47	: 100	:: Litharge	139,5	: 34,1	
Sulphate of Lead -	(8)	279	: 100	:: Litharge	139,5	: 50,0	Sulphuric acid
					3 Oxygen =	30	
Galena - -	(9)	86,64	: 13,36	:: Lead	129,5	: 20	Sulphur (*f*)
Ditto -	(10)	85,1	: 13	:: Lead	129,5	: 19,8	
Phosphate of Lead	(11)	380,56	: 100	:: Litharge	139,5	: 37,4	Phosphoric acid
					2 Oxygen	20	
Phosphoric acid -	(12)	53,28	: 46,72	:: Phosph. acid	37,4	: 17,4	Phosphorus (*g*)
Oxalate of Lead -	(13)	296,6	: 100	:: Litharge	139,5	: 47,0	Oxalic acid (*h*)
Carbonate of Barytes	(14)	100	: 352,57	:: Carb. acid	27,54	: 97	Barytes (*i*)
Sulphate of Barytes	(15)	34	: 66	:: Sulph. acid	50	: 97	
Sulphate of Strontia	(16)	42	: 58	:: Sulph. acid	50	: 69	Strontia (*k*)
Common Salt -	(17)	134	: 88	:: Chlorine	44,1	: 29	Sodium (*l*)
					10	10	
Ditto - -	(18)	100	: 114,78	:: Mur. acid	34,1	: 39,1	Soda
Subcarbonate of Soda	(19)	41,24	: 58,76	:: Carb. acid	27,54	: 39,1	
Muriate of Potash	(20)	100	: 173,47	:: Mur. acid	34,1	: 59,1	Potash (*m*)
						10	
						49,1	Potassium
				add Oxymuriatic acid or Chlorine		44,1	
Muriate of Potash from Potassium	(21)	32	: 60,8	:: Potassium	49,0	: 93,2	Mur. Potash

(1) Biot and Arago (2) Ditto (3) Experiment (4) Berzelius (5) Berzelius
(6) Marcet (7) Berzelius (8) Berzelius (9) Ditto (10) Thomson
(11) Berzelius (12) Rose (13) Berzelius (14) Ditto (15) Klaproth
(16) Ditto (17) Davy (18) Berzelius (19) Ditto (20) and (21) Ditto

Sulphate of Magnesia	(22)	67	: 33	:: Sulph. acid	50	: 24,6	Magnesia (*n*)
						50	
						74,6	Sulph. Magnesia
Epsom Salt 100 -	(23)	51,5	: 48,5	:: 7 Water	79,3	: 74,4	
Specific Gravities -	(24)	,07321	: 96913	:: Hydrogen	1,327	: 17,54	Azote (*o*)
				3 Hydrogen = 3 × 1,327		3,98	
Ammonia -	(25)	1 Azote + 3 Hydrogen				= 21,52	Ammonia (*p*)
Subcarb. Ammonia	(26)	56,02	: 43,98	:: Carb. acid	27,54	: 21,6	
Bi-carb. Ammonia	(27)	11,8	: 28,2	:: 2 Carb. acid	55,1	: 21,6	
Nitrate of Potash -	(28)	46,7	: 53,3	:: Potash	59,08	: 67,45	Nitric acid (*q*)
Nitric acid -	(29)	1 Azote + 5 Oxygen 17,54+50				= 67,54	
				2 Water = 2 × 11,32		= 22,64	
						90,18	Liquid Nitric acid
Marble dissolved -	(30)	476	: 681,¾	:: Carb. Lime	63	: 90,23	S. G. 1,50
Oxid of Iron -	(31)	22,5	: 77,5	:: Oxygen	10	: 34,5	Iron (*r*)
						10	
Sulphate of Iron -	(32)	28,9	: 25,7	:: Sulph. acid	50	: 44,5	Oxid of Iron
Oxid of Zinc -	(33)	24,41	: 100	:: Oxygen	10	: 41	Zinc (*s*)
Black Oxid Copper	(34)	20	: 100	:: Oxygen	10	: 40	Copper (*t*)
						10	
Sulphate of Copper	(35)	32	: 32	:: Sulph. acid	50	: 50	Oxid of Copper
Muriate Silver -	(36)	19,05	: 80,95	:: Mur. acid	34,1	: 145	Oxid of Silver
						10	
						135	Silver (*u*)
Horn Silver -	(37)	24,5	: 75,5	:: Chlorine	44,1	: 136	
Sulphuret Silver -	(38)	14,7	: 100	:: Sulphur	20	: 136	
Red Oxid of Mercury	(39)	8	: 100	:: Oxygen	10	: 125	Mercury (*v*)
Ditto - -	(40)	30	: 380	:: Oxygen	10	: 126,6	
Corros. Sublimate -	(41)	2 × 67	: 380	:: Chlorine	44,1	: 125,4	
						10	
Protoxid - -	(42)	1 Oxygen + 2 Mercury -				: 262	Protoxid ☿
Protoxid -	(43)	4	: 104	:: Oxygen	10	: 260	
Calomel - -	(44)	11,5	: 88,5	:: Mur. acid	34,1	: 262	

(22) Henry (23) by experiment (24) Biot and Arago (25) by Hypothesis (26) Gay Lussac
(27) Berthollet (28) Richter (29) by Hypothesis (30) R. Phillips (31) Thenard
(32) Berzelius (33) Gay Lussac (34) Chenevix (35) Proust (36) Marcet
(37) Davy (38) Wenzel (39) Fourcroy and Thenard. (40) Davy
(41) Davy (42) by Synthesis (43) Fourcroy (44) Chenevix

Water contained in crystallized Salts.

Sulphate of Copper	(45) 100	: 36,3	:: 156,6	:	56,8 =	5 × 11,36	Water (w)
Sulphate of Iron -	(46) 100	: 45,4	:: 173,8	:	79,0 =	7 × 11,28	
Sulphate of Zinc -	(47) 100	: 44,3	:: 180,2	:	79,8 =	7 × 11,40	
Sulphate of Magnesia	(48) 100	: 51,5	:: 153,9	:	79,3 =	7 × 11,33	
Glauber Salt -	(49) 100	: 56	:: 202,3	:	113,1 =	10 × 11,31	
Muriate of Barytes -	50) 100	: 14,8	:: 153,6	:	22,8 =	2 × 11,48	

(45) Berzelius (46) Ditto (47) Lost by heat (48) By heat (49) Berzelius (50) Ditto.

In this table I have selected in most cases double evidence from different sources, in order that the inferences might receive confirmation from their concurrence. Number (29) may be noticed as a result anticipated from preceding data, and found to coincide with remarkable accuracy.

In the distillation of nitric acid from nitre, the whole of the acid may be obtained, if we employ enough of sulphuric acid to convert the residuum into bi-sulphate of potash. In this case each portion of potash, from which dry nitric acid is separated, will displace the water from two equivalent quantities of sulphuric acid, and each portion of nitric acid weighing 67,54 will be found combined with 22,64 of water. Hence 90,18 of liquid nitric acid so obtained should dissolve the equivalent 63 of carbonate of lime. And in fact, by an experiment carefully conducted on a large scale by Mr. PHILLIPS,* it appears that 681$\frac{3}{4}$ of such acid did dissolve 476 of marble, which is in the proportion of 90,18 to 62,96, corresponding with the estimate within $\frac{1}{1500}$ part, a degree of coincidence rarely to be found even in the repetition of the same experiment by the most skilful analyst.

The specific gravity of this acid was found to be 1,50.

* Experimental Examination of the Pharm. Lond. by R. PHILLIPS.

Fig. 3.

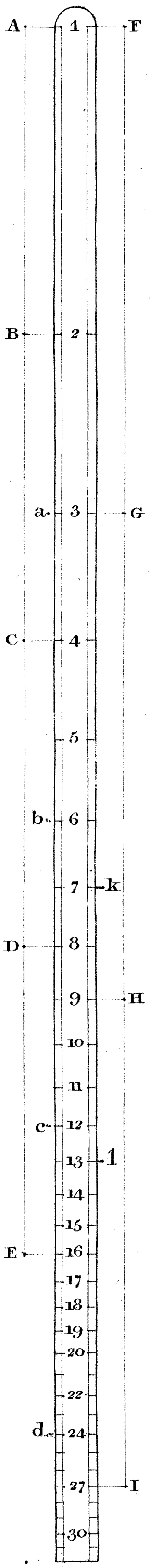


Fig. 2.

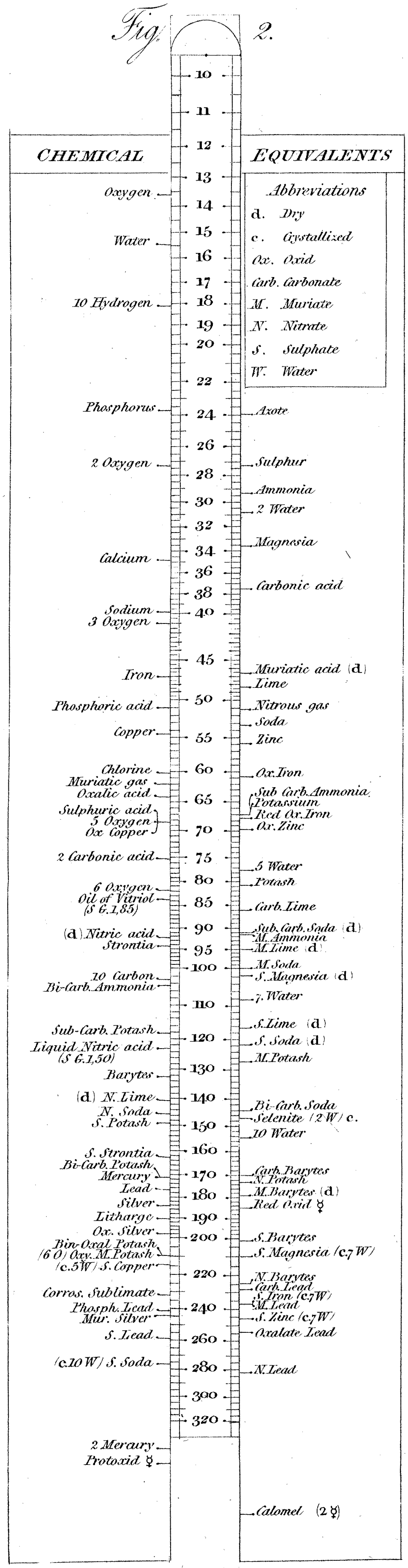
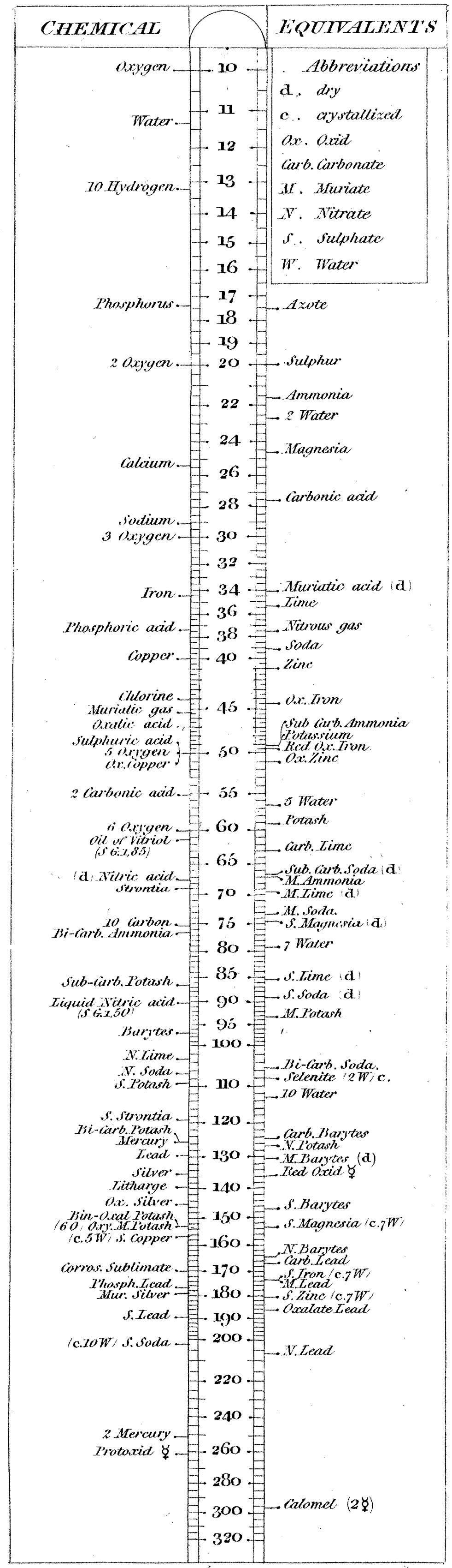


Fig. 1.



J. Basire sc.